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Research Priorities for the Culture of Arctic Charr, *Salvelinus alpinus* (L.), in Atlantic Canada

J.L. Tabachek and B.G.E. de March

Central and Arctic Region
Department of Fisheries and Oceans
Winnipeg, Manitoba
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1991

RESEARCH PRIORITIES FOR THE CULTURE OF ARCTIC CHARR, Salvelinus alpinus (L.), IN ATLANTIC CANADA

by

J.L. Tabachek and B.G.E. de March

Central and Arctic Region

Department of Fisheries and Oceans

Winnipeg, Manitoba R3T 2N6

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ABSTRACT

Tabachek, J.L., and B.G.E. de March. 1991. Research priorities for the culture of Arctic charr, Salvelinus alpinus (L.), in Atlantic Canada. Can. Ind. Rep. Fish. Aquat. Sci. 211: iv + 15 p.

This report summarizes the research priorities for Arctic charr aquaculture in Atlantic Canada. The report resulted from a tour of Atlantic Canada by the authors in March 1991 and was sponsored by the Aquaculture Science Component of the Atlantic Fisheries Adjustment Program. The purpose of this travel was to consult with those in the aquaculture industry and identify the areas in which Arctic charr research should be focused in order to meet the needs of the industry. Insufficient supply of eyed eggs and viable fry was perceived to be the major impediment to the development of the Arctic charr industry. Improvements require research on the effects of nutrition, temperature, photoperiod and stressors such as handling, crowding and anaesthetics on reproductive success. Establishing the optimum incubation conditions for successful development of eggs was considered a high priority. Improvements in both the survival of swimup fry and the growth of charr from fry through to 3-4 kg size requires research in nutrition and environmental conditions. Pigmentation of market size fish was of importance to growers and requires research in nutrition and stock development. Stock development and genetics were areas which require continuing research in evaluating wild stocks for their potential under different aquacultural environments. Each of the research priorities is discussed in detail.

Key words: reproduction; egg incubation; early rearing; animal nutrition; fish genetics; environmental conditions; pigmentation; stock development.

RÉSUMÉ

Tabachek, J.L., and B.G.E. de March. 1991. Research priorities for the culture of Arctic charr, Salvelinus alpinus (L.) in Atlantic Canada. Can. Ind. Rep. Fish. Aquat. Sci. 211: iv + 15 p.

Le présent rapport résume les priorités de recherche dans le domaine de l'aquaculture de l'omble chevalier dans le Canada atlantique. Le rapport fait suite à une tournée du Canada atlantique entreprise en mars 1991 par les auteurs dans le cadre du Programme d'adaptation des pêches de l'Atlantique (Science aquacole). L'objectif de cette tournée consistait à consulter les intervenants de l'industrie aquacole pour déterminer dans quels domaines devrait s'orienter la recherche sur l'omble chevalier pour répondre aux besoins de l'industrie. L'approvisionnement insuffisant en oeufs oculés et en alevins viables a été perçu comme le principal obstacle au développement de l'aquaculture de l'omble chevalier. Pour améliorer cette situation, la recherche doit porter sur les effets de la nutrition, de la température, de la photopériode et de facteurs de stress comme la manipulation, la surpopulation et les anesthésiques sur le succès de la reproduction. On a considéré comme très prioritaire la détermination des conditions d'incubation optimales pour obtenir un bon développement des oeufs. L'amélioration de la survie des alevins à nage libre et de la croissance de l'omble chevalier (de l'alevin à l'adulte de 3-4 kg) nécessite des recherches sur la nutrition et les conditions environnementales. La pigmentation des poissons de taille commerciale est un sujet qui préoccupait également les producteurs et qui nécessite des recherches en nutrition et en développement des stocks. La génétique et le développement des stocks sont des domaines qui exigent des recherches continues sur l'évaluation des stocks sauvages exposés à diverses conditions d'élevage. Toutes les priorités de recherche sont discutées en détail.

Mots-clés: reproduction; incubation des oeufs; élevage précoce; nutrition animale; génétique des poissons; conditions environnementales; pigmentation; développement des stocks.

INTRODUCTION

In the past 10 years, the potential of Arctic charr, (Salvelinus alpinus (L.), as an aquaculture species has been demonstrated and has received much interest from the aquaculture industry across Canada. Much of the current knowledge of intensive culture of Arctic charr has been the result of research at the Rockwood Aquaculture Research Centre (RARC), Gunton, MB, and the Freshwater Institute Science Laboratory, Winnipeg, MB (Papst and Hopky 1989; Tabachek 1991). These areas of research include nutrition, genetics, physiology, husbandry and biotechnology. Strains of Arctic charr from Canada (Labrador and the Northwest Territories) and Norway are raised at RARC and the third generation of some strains has been established. In 1984, a certified strain of Labrador charr was established and eggs have been distributed across Canada since late 1987. To date, eggs have been shipped to 43 growers and/or research facilities across Canada including 15 producers and/or research facilities in Atlantic Canada (Newfoundland (6), New Brunswick (4), Nova Scotia (3), Prince Edward Island (2)). In addition, Arctic charr eggs have been distributed from the Huntsman Marine Science Centre (HMSC), St. Andrews, NB, and from wild stock. Research on raising Arctic charr in cages in salt water has been conducted in New Brunswick (Delabbio and Glebe 1987; Delabbio et al. 1988, 1990). In the last few years, research on various aspects of growth and physiology has been conducted at Memorial University's Marine Science Research Laboratory and the Marine Institute in St. John's, NF.

Arctic charr grow well at the low temperatures typical of some Canadian waters (Uraiwan 1982; Baker 1983). They grow well at high densities with a growth rate that is superior to rainbow trout (Oncorhynchus mykiss) at densities over 60 $kg \cdot m^{-3}$ (Baker and Ayles 1990). Some strains of Arctic charr are more tolerant to hypoxia than are other salmonids. These attributes make charr a good species for aquaculture. Currently, Arctic charr command a high price relative to other salmonids. Talley (1991) reported a rebound in charr prices in late 1990 from a fall slump. He stated that in December 1990 prices were $12.78 per kg ($5.75 per lb) for Arctic charr compared to $5.00 - 6.22 per kg ($2.25 - 2.80 per lb) for rainbow trout. Large 1.8-2.7 kg (4-6 lb) Arctic charr sold at $12.22 - 14.44 per kg ($5.50 - 6.50 per lb) while 2.7-3.6 kg (6-8 lb) North American Atlantic salmon (Salmo salar) were selling at $7.65 per kg ($3.45 per lb). He stated that deep red-colored flesh was a critical factor in obtaining the high price for Arctic charr and that large charr with light-colored flesh sold for as little as $7.78 per kg ($3.50 per lb).

In contrast to the above advantages to raising Arctic charr, there are also some disadvantages. There is a wider variation in growth rates between individuals in a population of Arctic charr than is found with rainbow trout (Papst and Hopky 1984, 1989) and the slowest growing portion of the population may never reach market size. Another disadvantage in raising Arctic charr is the low hatchability and poor survival at first-feeding of some stocks. For example, the survival to hatch of the Labrador stock is variable and often low compared to the Nauyuk Lake and Norwegian strain, while the survival of fry at first-feeding is extremely low for the Norwegian charr compared to the other stocks, especially at low water temperatures.

TRAVEL IN ATLANTIC CANADA

In March 1991, the authors submitted a proposal for a grant from the Aquaculture Science Component of the Atlantic Fisheries Adjustment Program (AFAP) to investigate the status of Arctic charr culture in Atlantic Canada and identify research which was needed in order to improve it. The proposal stated that "The main objective is to determine, by consulting with industry and identifying their needs, the areas in which Arctic charr research should be focused. The sub-objective is to establish and/or improve communications with clients in the aquaculture industry in the Atlantic Region who are associated with Arctic charr culture - producers, feed manufacturers, and researchers". The third objective was to discover the areas in which other people were working and explore the possibility of entering into collaborative research projects in the Atlantic region. Although the proposal requested funds for three people to participate, sufficient funding was received for two people to travel to Atlantic Canada.

During the trip, from March 4 to 13, 1991, meetings were held with 10 of the 15 people in Atlantic Canada who had received Arctic charr eggs from RARC. In addition, three others were contacted only by telephone. Arctic charr were being raised at seven sites that were visited, with poor weather and road conditions preventing us from visiting two others. In addition, two sites were visited where Arctic charr were not being reared. In Newfoundland, no growers' facilities were visited but R. Penney organized a one-day workshop in St. John's, NF, with Arctic charr growers and researchers. The names of people with whom we met are listed in Appendix A and those with whom we spoke only by telephone are listed in Appendix B.

At six locations where meetings were organized, the authors gave a slide presentation. J. Tabachek presented information on i) culture systems at RARC, ii) differences between the stocks of Arctic charr raised at RARC, iii) research that has been conducted with Arctic charr on nutrition, physiology, environmental conditions and stock differences and iv) the Technology Transfer program through which Arctic charr eggs are distributed from RARC to clients across Canada. B. de March presented the results of her research in genetics. Three handouts were distributed: i) List of publications

produced by researchers working with Arctic charr at RARC, ii) Arctic Charr Culture Bulletin No. 1, 1990 and iii) example of the Technology Transfer Agreement which the Central and Arctic Region, Winnipeg, MB, has established with clients across Canada. Highlights of these presentations and the handouts have been reprinted in the Proceedings of the Arctic charr Culture Workshop held in Newfoundland (Penney 1991).

THE ARCTIC CHARR AQUACULTURE NICHE IN ATLANTIC CANADA

Since Arctic charr have only been grown for a short period of time, their identity or market niche is not as well established as that of rainbow trout, Atlantic or Pacific salmon (Oncorhynchus). Some growers in Atlantic Canada are raising small numbers of charr with hopes that they will grow faster than trout at their cold-water facilities and/or that they will have access to a new market niche. Several growers in the Maritimes and in western Canada have successful operations which produce pan-sized fish for restaurants or supermarkets. It was generally agreed that the market for Arctic charr can be increased and that charr will compete with either speckled trout (Salvelinus fontinalis), rainbow trout and/or salmon in the marketplace. It is anticipated that these markets will exist in Ontario and/or the eastern United States if the proper marketing infrastructures develop and that pan-sized fish, selling at prices between those of rainbow trout and cultured salmon, will be produced for restaurant markets. One grower in the Yukon has been marketing 1.8-2.7 kg (4-6 lb charr) selling them at the high prices given in the Introduction. Based on both the high market price of 1.8-2.7 kg (4-6 lb) charr and on the current shortage of eggs and fry, some growers believed it may be more cost-effective to grow charr to a larger size before marketing them. Growers speculated on how market price would be affected as more product becomes available for market. There was concern that, if too many producers begin to produce Arctic charr based solely upon the expectation of a high market price, the increased supply could result in a decrease in the market value. If that were to happen, they could all lose money by the time they are ready to market their product. They suggested that business plans be made based on much lower market prices to build in a margin of safety. Quality of the product and marketing are discussed under Priorities 13 and 14.3, respectively.

In the Maritimes, we met people who were raising charr or were interested in raising charr. Most growers who were raising Arctic charr were raising them on a small-scale trial basis while raising other species of trout or salmon. The farms generally had cold spring water which the growers believed to be well-suited to raising charr. There was concern raised by growers in isolated areas that, in future, small isolated facilities could find it difficult to market fish when competing with large facilities close to urban centers.

In Newfoundland, Arctic charr has been identified as a potentially important aquaculture species for the following reasons: i) the relatively constant and low temperature ranges available in lakes, ii) the abundance of running ground water, iii) the suitability of some coastal areas, and iv) the availability of alternative feed ingredients from by-products of the fishing industry (Robbins et al. 1990). The fact that charr is native to the island suggests that local habitats may be suitable for charr culture. Unlike the Maritimes, Newfoundland had few existing aquaculture facilities, and growers were forced to raise an unfamiliar species and develop facilities simultaneously.

INSUFFICIENT SUPPLY OF ARCTIC CHARR EGGS AND FRY

Insufficient supply of eggs and high mortality of fry were viewed as the major impediments in the development of the Arctic charr industry. A sufficient and dependable supply of eggs and good survival of fry is required for growers to develop production plans. The current shortage of eggs for the industry is due to the following reasons:

a) Most producers across Canada have Arctic charr which have not reached maturity or have stocks in which only a small percentage of fish have reached maturity.

b) Adult charr may not spawn every year.

c) Growers who have mature broodstock are keeping eggs for their own future production.

d) Some strains of Arctic charr have poor and/or inconsistent egg survival while others have high egg survival with less variability between fish and between years. However, strains with high egg survival may not be available (due to provincial import restrictions) or they may have other undesirableable characteristics. In addition, survival of eggs to the eyed stage is often low from first-time spawners.

e) Eggs from uncertified facilities cannot be transported across provincial boundaries without special permission and/or conditions. Some provinces require uncertified eggs to be held in quarantine. They may also require sampling of reproductive fluids or destruction of broodstock to test for certifiable diseases. Destruction of broodstock obviously reduces the number of potential spawners from that facility.

f) Growers in Newfoundland cannot import eggs from British Columbia or the Yukon because they are not permitted to import eggs from west of the Continental Divide.

g) One supplier of eggs has a franchising agreement which restricts egg and fry distributions. Several growers in the Maritimes, Newfoundland and Maine who purchased licenses for Brandy Cove® Arctic charr through the Huntsman Marine Science Center (HMSC), are committed to selling their eggs and live fish only to other licensees. Therefore, they are not readily available to the majority of growers. Buying a license for Brandy Cove® Arctic charr was considered to be expensive and this has limited the number of people who have entered into these agreements. Costs are $2500 for the license plus 3% of sales thereafter. In addition, there is the cost of $0.20-0.30 per eyed egg, $1.00 per 10-15 g fish, $2.00 per 25-30 g fish and $3.00 per 50 g fish.

h) It has become increasingly difficult to collect eggs from the wild throughout Canada. Charr in some areas have been found to carry pathogens listed in Schedule II in the Fish Health Protection Regulations made under the Fisheries Act of Canada (Department of Fisheries and Oceans, 1984) and therefore eggs from these stocks cannot be certified. Native land claims have made it more difficult to obtain permits. In addition, egg collection requires both funds and experienced staff and guides who know where and when spawning occurs. Spawning occurs in remote areas often accessible only by helicopter. Adverse weather and fog conditions during the spawning time can prevent shipping eggs during an acceptable period of time and result in poor survival.

These factors contribute to the present short supply of eggs. This may improve in future, but the following steps should be taken to ensure that it does improve:

a) Support research to improve reproduction and increased survival of eggs and first-feeding fry. (See Priorities 1 and 2).

b) Provide staff and funds to support travel for the collection of eggs from the wild. These wild stocks should be evaluated for production characteristics (growth, appearance, survival at each stage, and reproductive abilities). A strategy for evaluation should be developed to obtain as much information from these collections as possible. (See Priorities 5 and 6.4).

c) Provide funds for the construction of quarantine facilities. Quarantine facilities are needed to receive eggs from the wild or from uncertified facilities. Presently, there are uncertified stocks of Arctic charr at RARC that originated from Labrador, Nauyuk Lake in the Northwest Territories and Norway. The two uncertified Labrador broodstocks represent a much larger gene pool than the certified Labrador stock which has been widely distributed throughout Canada. However, the certified broodstock facility is too small to house additional stocks. For eggs from these uncertified broodstocks to become available to the industry, funds would be required to build a larger certified broodstock facility at RARC and/or growers would need quarantine facilities to receive them. Either option would probably require additional staff for RARC or for growers.

Improving the supply of eggs by implementing the above four measures is essential for expanding commercial Arctic charr culture. Once egg supply is improved, other requirements described in this report will be more readily addressed by research. The problems of reproduction, egg incubation and early rearing (Priorities 1 and 2, respectively) need to be overcome before selecting and evaluating new strains of charr for aquaculture (Priority 5). If these problems are not solved, genetic variability may be reduced and individuals with good attributes for aquaculture may be eliminated from populations. (See Priority 6.4). Once these problems are resolved, methods should be defined to improve growth and reduce variability, and expand commercial possibilities through improvements in cage culture techniques or recirculation technology.

RESEARCH PRIORITIES

Research requirements for Arctic charr culture are listed according to priority. The priorities were determined by a combination of the amount of interest perceived to exist for each area in combination with our own experience. For the most part, the areas were first mentioned by the people with whom we met. However, we raised concerns about egg quality and variation in growth rate during our presentations which preceded the discussions and it is hoped that this did not unduly bias the priorities towards these areas. Many of the research areas are interrelated which made it difficult to make an absolute ranking. Readers are encouraged to read the entire report since overlap exists between several areas.

1 REPRODUCTION

Growers who had experience with reproductive Arctic charr gave reproduction or broodstock development as

one of the priority areas for research. Other growers who had experience only with the eyed egg to grower size were more likely to raise the issues of high mortality at first-feeding, size variability, and pigmentation as the high priority areas.

There are significant differences in egg survival i) between strains (Krieger 1987), ii) between individual females within a strain and iii) between years for given females (Tabachek and de March 1990). Different stocks also spawn at different times and for different spawning periods. Specific techniques need to be defined for producing broodstock that will spawn within a reasonable window of time as well as producing good quality eggs for several years. Maintaining fish for broodstock is costly in terms of tank space and time. In order to plan production schedules and minimize the number of broodstock that need to be maintained, research is required in the area of reproduction.

At RARC, the survival of eggs to the eyed stage has been high with the Nauyuk Lake and Norwegian strains (75-85% and 75% respectively in 1990/91). In contrast, survival to the eyed stage of the certified Labrador strain was 50, 72, 35 and 64% for the past four years. Even when overall survival was only 35%, survival of eggs from individual females ranged from 0 to 99%. The research of B. de March, in which eggs from individual females were divided into batches and fertilized with sperm from different males, suggests that egg survival is related entirely to egg quality, not sperm quality. Eggs will often begin to develop and then die just prior to reaching the eyed stage. Other growers in western Canada have had the same experience with the Labrador strain as that experienced at RARC. Sufficient numbers of ripe fertile males occurred in all populations during the spawning season and these were generally ripe for an extended period of time.

In Atlantic Canada the survival of fry was reported to be a problem. At RARC, high mortality of fry is associated with Norwegian, not Labrador charr. Growers in Atlantic Canada have received eggs from three sources: i) relatively small numbers of eggs (1,600-10,000, average 4,200) from RARC, ii) larger numbers of eyed eggs of the Brandy Cove® strain from B. Glebe of HMSC and franchised producers, and iii) eggs from Brook Valley Fish Hatchery, Prince Edward Island in 1990. A high degree of satisfaction was expressed with the eyed eggs obtained from RARC. Hatchability was high and the fry started feeding successfully with only one grower having poor survival. Eggs produced in the Maritimes in the 1990/91 season, but which had also originated from the 1984 collecting trip to Labrador, had survival to the eyed stage which was often considerably higher than those from RARC. However, the eggs produced in the Maritimes were often smaller than those received from RARC and, with no exceptions, many "pin-heads" (emaciated fry which do not consume feed) were produced and high mortalities occurred before or at first-feeding. It is not known if the mortalities during incubation and swimup were related to the same problem but manifested at different times or were entirely different problems.

Areas in which research is most relevant to egg and fry survival are Priorities 1.1, 1.2, 1.3 and 2.

1.1 Broodstock nutrition

It is well known that diet can have an impact on egg survival, fecundity and the timing of spawning. There are many individual nutrients to consider in broodstock nutrition - essential fatty acids, specific vitamins (especially vitamins C and E) and minerals, pigments, energy and protein. As yet, almost no research has been done on the nutritional requirements of Arctic charr broodstock except for current research on the effects of lipid and vitamin E (Tabachek, unpublished data). Until research is conducted, growers will continue to use salmon or trout broodstock diets and hope that they meet the requirements of Arctic charr sufficiently. In addition to establishing nutritional requirements, the effects of feed intake on reproduction of Arctic charr should be investigated to provide guidelines for feeding prior to spawning. The effects of withholding feed just prior to spawning and the effects of extended withholding of feed for males and non-spawning females should be investigated. It has been observed that some charr do not resume feeding after the spawning season. These fish become emaciated, produce very few, if any, eggs the following year and eventually die. (See Priority 7). Improving the palatability of feeds through the use of flavour enhancers and/or semi-moist soft feeds should be investigated to determine if this problem can be overcome.

Research on the joint effects of nutrition and environmental factors (temperature, photoperiod) would also be of value if the facilities are available. (See Priority 4).

1.2 Environmental factors and hormones

Natural populations of Arctic charr experience strong seasonal changes in temperature, photoperiod, food availability and type, and sometimes crowding. It is not known to what extent Arctic charr are dependent on these changes for the timing of reproduction and growth. Observations at RARC strongly suggest that dramatic sudden seasonal changes in temperature and photoperiod can synchronize ovulation. Conditions were 12°C and 18 hours light in "summer" starting in March, and 6°C and 6 hours light in "winter" starting in September, with photoperiod changes being instantaneous and temperature changes occurring over one week. Females in one Labrador stock spawned over a period of two weeks, rather than the usual four months,

after being exposed to a continued "winter", one sudden "summer", and one sudden "winter" over a period of one year. A longer "winter" has been shown to delay slightly the date of ovulation in Norwegian and Nauyuk stocks. Use of very low temperatures for inducing or synchronizing ovulation merits further investigation since it is known that natural populations often spawn near the time of freeze-up. These methods should be investigated in detail to establish definite recommendations for growers.

More extensive research on the use of hormones such as luteinizing hormone-releasing hormone (LHRH) to induce ovulation is required. There is also a need for information on the production of natural hormones of Arctic charr. M. Jansen, L. Crim and W. Van Toever planned to begin this research in 1991/92 at Integrated Aquatic Systems, Prince Edward Island.

1.3 Effects of stressors on ripening females

There is little information available on the effects of stressors on ripening females, but there are cases in which handling, anaesthetics, crowding, high temperatures, hypoxia and poor water quality were suspected of affecting the quality of the eggs. All these areas warrant investigation.

2 EGG INCUBATION AND EARLY REARING CONDITIONS

Most charr eggs in Canada are incubated at 6-8°C, temperatures at least two degrees higher than those encountered under natural conditions. Mortalities of both eggs and first-feeding fry suggest premature depletion of yolk sac nutrients, a phenomenon which has been shown to be associated with warm temperatures in other species. Experiments that compare the hatching success and fry survival of the eggs from the same females at several low temperatures need to be done. Baker (1981) transferred eyed eggs (incubated at 5.4°C) to one of four temperatures between 6.3 and 12°C. There was 100% hatching at all temperatures, but survival to swim-up was lower at 12°C than at temperatures of 10°C or less. He recommended that late incubation temperature be kept at 8°C or less. This research should be extended and should include early incubation temperatures.

Under natural conditions, eggs often hatch synchronously due to elevated spring water temperatures. Studies with other species have shown that forced hatching yields poorly developed fry with larger yolk sacs and hence delayed time to first-feeding, while delayed hatching forced by cold temperatures yields fry with little or no yolk sacs and a high hunger demand. It is not known whether forcing or delaying hatching can improve survivorship but this should be thoroughly investigated for charr.

Many growers experienced high mortality (20-30%) with their charr immediately prior to or at first-feeding. Some facilities had "pin-heads" that did not initiate feeding at all and/or were so small that they were lost through the screen in the incubator or trough. At RARC, mortalities up to 80-90% at first-feeding were observed with the Norwegian strain, while mortalities with the Labrador and Nauyuk strains were considerably lower. A combination of increasing the water temperature to 10°C (from 7°C) and feeding a semi-moist commercial diet (compared to a commercial dry diet) reduced mortality to 17% with the Labrador strain and to 63% with the Norwegian strain (Tabachek and Krieger, unpublished data). The increase in temperature had a greater positive effect on survival than the change in diet.

Finding ways to initiate feeding should be the first step in research on early rearing. While charr fry survived better on a semi-moist diet from one company than on a dry diet from another company, the composition and the ingredients used in these two diets differed. Thus, the critical differences between the two feeds are not known. The effect of moisture per se on survival should be examined. In addition, research should be conducted on flavour enhancers to encourage initial feeding and on the use of very high quality ingredients, such as high quality fish meal, to ensure that diets are as digestible as possible.

In the wild, charr fry may seek out warm shoreline areas, particularly ones that receive drift from streams or marshes, and may feed through the day and night. Other environmental factors that might be important in the natural habitat should be examined further. For example, one grower believed that bright light depressed first-feeding. Research might also include evaluating the effects of potentially important physical factors such as light intensity, photoperiod, frequency of feeding and tank morphometry. (See Priority 8.1).

3 NUTRITION

Nutrition is a key element in the rearing of any animal. Nutritional requirements depend on both the species and stage of development. As yet, there has been little research published in Canada or Scandinavia on the nutritional requirements of Arctic charr.

Two feed manufacturers in New Brunswick were prepared to utilize information on the nutritional requirements of Arctic charr but were not able to conduct their own intensive research. They depend on receiving information on research, conducted by others, which they can apply in formulating diets for Arctic charr. One of these companies was able to respond to the industry's request for Arctic charr diets and use information from research done by others to manufacture a diet with more ideal protein and lipid levels.

3.1 Stage-specific diets

In the case of other salmonids such as rainbow trout and salmon, specific diets have been developed for first-feeding, fry, fingerlings to pan-size, and for broodstock. Few such specialized diets exist for Arctic charr.

Across Canada, problems have been encountered with initiation of feeding at swimup and with quality of broodstock. These problems and possible solutions are described in more detail in Priorities 1.1, 2 and 4.

Research at RARC with Arctic charr fingerlings (Tabachek 1984) showed that the Norwegian strain utilized some feeds much more poorly than the Labrador strain. Considering the many differences in the natural environment of the two strains, research on Norwegian charr may not be entirely applicable to Canadian strains. Research by Tabachek (1986) showed that Nauyuk Lake Arctic charr fingerlings require diets that are higher in protein and lipid than rainbow trout require. That research showed that charr fingerlings require a diet containing 54% protein and 20% lipid for maximum growth, but a diet containing 44% protein with 20% lipid would be more cost-effective even though growth is somewhat slower. The essential fatty acid requirements of charr fingerlings are also being investigated at RARC by X. Yang of the University of Manitoba. At Integrated Aquatic Systems in Prince Edward Island, several diets for Arctic charr were being evaluated at 2 and 6°C. This research, funded by an AFAP grant, was being done in collaboration with feed manufacturers and researchers in Prince Edward Island and New Brunswick.

Requirements need to be established for individual essential amino acids and fatty acids, vitamins, minerals and carbohydrates, as well for as energy requirements. Toxic levels of some nutrients should also be identified.

3.2 Pigmentation

The topic of pigmentation was raised by almost every group that we met. Pigmentation is of concern because buyers expect charr to have salmon-colored flesh. As stated in the Introduction, premium prices were obtained for charr with a deep red-colored flesh.

Pigmented feeds containing astaxanthin or canthaxanthin are available, but research is required on the levels of dietary pigment required to achieve the desired level of pigmentation in Arctic charr. One preliminary experiment on uptake of astaxanthin and canthaxanthin in Labrador charr has been completed in Newfoundland (Shahidi et al. 1991). The efficacy of different sources of dietary pigments should also be investigated.

In Atlantic Canada, water temperatures are low (2-4°C) for several months during the winter. If feed intake decreases with water temperature, pigment intake is decreased and the color of the flesh can be reduced. If fish are to be marketed during the winter and early spring, this loss of color could reduce sales and market price of the product. Growers and feed manufacturers need more information on loss of pigmentation and methods of overcoming this problem.

Growers reported variability in the amount of pigment that is deposited and/or retained between individuals in the population. Since buyers expect a consistent product, methods of reducing this variability should also be investigated. In addition, since both a pan-size and a 1.8-2.4 kg (4-6 lb) fish are potential products, different diets and feeding strategies might be required for the two products. There is some evidence that some strains of charr take up pigment more readily than other strains and attain a deeper red-colored flesh. Selection for fish which take up pigments readily and have low variability in this trait should be considered. Some fish in a population have lighter skin coloration than others. A question that needs to be answered is whether these fish take up pigment at the same rate as charr with normal skin color.

3.3 Low pollution diets

Manufacturers and growers talked about the growing concern for the environment. In future, effluent from fish farms may be monitored and regulations imposed. Feed manufacturers have started to change their formulations. These new formulations reduce the levels of soluble phosphorus and nitrogen, have higher levels of protein and fat and use highly digestible ingredients. They result in increased feed efficiency and decreased fecal wastes and thus have less impact on the environment. Feed manufacturers will continue to need information from research to make additional changes in diets for Arctic charr and other species.

3.4 Feeding strategies

In both tank or cage culture, there is a need for feeding tables that can be used from 0.5 to 19°C and for fish from fry to 3 kg (6.6 lb). Strategies for feeding pigmented feeds for pan-size and 1.8-2.7 kg (4-6 lb) fish should be developed. (See Priority 3.2). Efficient feeding is a desirable objective in reducing costs and in minimizing nutrients that may pollute the environment. (See Priority 3.3). Therefore, feeding tables should identify feeding rates which achieve both good growth rate and good feed conversion or efficiency.

The relative efficiencies of automatic feeders, demand feeders, and hand feeding for Arctic charr in tanks, raceways, and cages should be established. Strategies for ensuring that fish of all sizes receive feed should be developed. While size variability in charr appears to be primarily a genetic phenomenon,

circumstances that put small fish at a disadvantage could increase this undesirable variability. Optimum feed particle sizes have been reported for Arctic charr (Tabachek 1988; Robbins et al. 1990).

Arctic charr feed off the bottom of tanks more readily than other salmonids. While this behavior may be an advantage in tanks, it may prevent efficient feeding in cages with an open mesh bottom. Different strategies for feeding charr in cages should be investigated. (See Priority 8.1).

4 OPTIMUM ENVIRONMENTAL CONDITIONS

Identification of the optimum conditions for growth was of interest to most growers, particularly in view of the fact that charr appear to survive well under conditions considered stressful for rainbow trout. Environmental and biological factors of particular interest were fish density, water quality (including dissolved oxygen, ammonia and waste products), temperature, light intensity, photoperiod, salinity, and tank design parameters. These are discussed in other areas in relation to specific problems. (See Priorities 2 and 8.1). There are differences in the requirements of different strains of Arctic charr and the evaluation of optimum environmental conditions should be conducted for each strain.

Research is needed on the effects of combinations of factors. Those mentioned during the trip were the combined effects of temperature and photoperiod on maturation; of nutrition and temperature on fry survival and somatic growth; of salinity and temperature, and of water quality parameters and density, on growth at each life stage. There is also the need for more information on the combined effects of oxygen and high temperatures and of salinity and low temperature on survival in cages particularly with different strains of charr. (See Priority 5).

5 COLLECTION AND EVALUATION OF NEW STRAINS OF CHARR

It is generally believed, with good reason, that different strains of charr are suited to different culture conditions. These environmental tolerances are probably related to environmental extremes encountered in their native habitats. The identification and evaluation of some of these strains was considered as a priority, especially in Newfoundland, where charr are indigenous. Interest in this area was also expressed in New Brunswick, where regulations for introducing species and strains from non-indigenous stocks were stricter than other provinces, and the use of indigenous charr for aquaculture would overcome these concerns.

Physical attributes which might be important in different strains would be appearance, growth under different environmental conditions, reproductive characteristics, behavior and feeding characteristics, and salinity and temperature tolerance. A variety of physiological, biochemical, and tolerance studies could be important in identifying strains with different environmental requirements. Research such as that by M. Giles from the Freshwater Institute Science Laboratory on hemoglobin isomorphs and oxygen consumption is one example (Giles and Rystephanuk 1989; Giles 1991). Testing responses of different strains to stressors such as temperature, salinity, would also be informative.

Rearing wild stock to maturity or collecting eggs from adults in spawning beds is difficult. Moreover, wild stock used in collecting eggs and milt must often be sacrificed to meet provincial fish disease regulations. It is advisable for researchers who want to evaluate new strains to focus on only one or two strains at a time, and compare them to the Labrador strain grown under the same conditions at the same time. Also, new strains should be reared as individual families to understand the range of variability and the potential for selection. (See Priorities 6.1 and 6.2).

6 GENETICS

6.1 Variation in size and shape

It is well-known that charr exhibit more size variability than other cultured fish species. One grower viewed this as a positive characteristic since he could crop his tanks for the desired size of fish over an extended period of time. Other growers, particularly one with a larger and more streamlined operation, saw large size variability as an undesirable feature since it required more staff time for grading fish. Very high variability in a cohort (fish of the same age from the same population) is undesirable, since the smallest fish may never grow. Research has shown that a portion of the population may never reach market size (Papst and Hopky 1989).

Some strains or hybrids have, on average, more size and/or shape variability than others (de March 1991b). The differences in the range of variability in different families (fish with the same two parents) within strains is very conspicuous (de March 1991a, b). This variability has a genetic basis with some parents having the tendency to produce offspring with more size variability than others. Some environmental conditions have been shown to reduce or enhance the variability, but their effects are often small. The research suggests that variability in size and shape will probably decrease with selection as has happened with other domesticated species.

It is quite possible that size differences within a family or between families are correlated with differences in other traits, such as responses to stressors or ability to take up pigments. It is recommended that individual size measurements also be done in studies in which size is

not the main trait of interest in order to identify these genetic correlations.

The size variability characteristics of new strains of charr should be experimentally compared to a non-proprietary standard, such as the RARC Labrador strain, for which much is known.

6.2 Variation in maturation

"Precocious maturation" was identified as a problem by many growers. As discussions progressed, it became apparent that the problem may not necessarily be one of true precocious development, in which the male population segregates into two distinct types, but one of considerable variation in the age and size of sexual maturation in both males and females.

Like size variation, variation in maturation is believed to be a genetic phenomenon which can be modified with selection. However, no clear idea was perceived about what the industry needed. Selection for early maturing females and high fecundity is often inevitable in hatcheries, however, this characteristic may be genetically linked to early maturation in males, an undesirable feature. Selection for late maturation was believed to be important by growers who plan to market large 1.4-2.7 kg (4-6 lb) charr. The senescence of charr may prove to be a problem in this case. (See Priority 7).

Other methods of delaying sexual maturation, for example with hormones or the use of other common genetic engineering techniques, may prove to be worthwhile techniques for a variable species such as Arctic charr.

6.3 Inbreeding

Many people we met were concerned with the inbreeding that inevitably occurs when a small number of wild animals is used for seed stock. Although inbreeding was often a topic of discussion, perceptions about its relevance varied. On the one hand, inbreeding was considered to be inevitable and not a concern, since all domesticated species are inbred. On the other hand, there were concerns about inbreeding depression and an aesthetic desire to maintain stocks with genetic diversity or similar to the wild strain.

The Labrador charr now being distributed in Canada originated from HMSC and RARC. Both the Brandy Cove® strain from HMSC and the Labrador strain from RARC, were started from eggs from a few parents during the same collecting trip to the Fraser River in 1984. The second and third generations, possibly even resulting from two generations of sibling crosses, are now being distributed. We may have seen effects of inbreeding or founder effects at the different facilities we visited. For example, we saw differences in skin pigmentation and plumpness at facilities that appeared to have similar physical conditions.

These observations suggest that domesticated Arctic charr may eventually have characteristics which are due to chance, not due to planned selection for desirable traits. Care should be taken that new stocks are developed with a larger gene pool and with more attention to desirable aquaculture traits.

Some people thought research on inbreeding was required. At the moment, RARC has the only pedigreed (non-certified) stock of Labrador charr, and has avoided crossing closely-related animals in the selection program. This was no longer possible when the third generation was formed in 1990, and a number of sibs, half-sibs, cousins, etc. were mated. The combined effects of inbreeding and selection for superior fish will be monitored through the years.

6.4 Quantitative genetics and selection

B. de March's presentation on genetic research, which included results on the heritability of growth characteristics, on size variability, and on hybridization, generated considerable interest since it was related to the possibility of selection of lines better suited for aquaculture and to strategies in culture facilities. Assessing the potential for size selection, selecting for consistent lines, and describing the characteristics of hybrids were perceived as important research activities.

Research in quantitative genetics and selection for superior aquaculture strains are long-term and sometimes inefficient undertakings which cannot be done in all facilities. Families must be kept separate, environmental conditions must be standardized, and pedigrees of individual fish must be kept. To satisfy experimental design requirements, large numbers of females must often be spawned to make up for hatching failure. Such studies are on-going at RARC.

7 AGING AND REPEAT SPAWNING

The problem of aging or senescence was not mentioned by people we met, but may become a topic of interest as the industry develops. Cultured charr experience an accelerated life in captivity, possibly due to relatively high water temperatures. Broodstocks may start to deteriorate at a much earlier age than in the wild. In our strains of Labrador charr, spring die-off of some spawning females starts at four years, and no females have stayed productive past age 7 (de March and Baker 1990). For producing pan-size charr, the most desirable fish would mature at three or four years and produce good eggs for three years. For producing a large 1.8-2.7

kg (4-6 lb) charr, the most desirable fish would not mature until five years. The production of such fish may be partly a matter of husbandry and partly a matter of selection.

The question of how often Arctic charr will spawn was raised only by people who had charr broodstock in their facility. It has been our experience at RARC that some charr spawn each year while others do not. Some Labrador charr will spawn for the first time at three years, and most at four or five years. At RARC, one tank of 5 year old Labrador charr in which animals had been selected for small size at one year of age, and which contained many "slinks" (emaciated fish), produced an unexpected number of first-time female spawners at five years of age. Many of their siblings, which had been selected for their large size and which had been reared comparably, produced most first-time spawners at ages 3 and 4, and fewer at age 5.

Some facilities may be in the position to monitor the aging of broodstock in conjunction with other research. Fish should be tagged at first spawning and information about spawning frequency and success, culture conditions, and mortality should be collected.

8 SYSTEMS DEVELOPMENT

8.1 Evaluation of incubators, tanks, and cages

Throughout our tour of Atlantic Canada, we saw a variety of systems for incubating eggs and for growing fry and fish. Growers are very responsive to the behavior of their fish, and conditions that they thought stressed the fish were quickly changed. Several growers told us that they believed that tank shape and size, light intensity, flow patterns, and physical disturbances, affected the behavior of fish. It was apparent that they had taken these factors into account in arriving at decisions about alternative growing conditions.

For incubation, growers used Heath trays, and hatching baskets in troughs and circular tanks. There was no mention of problems associated with the designs of these incubators.

A great variety of tanks and troughs used to raise fry and fingerlings were observed throughout the trip. One grower raised fry in deep circular tanks, and we had not seen fry raised in such deep tanks before. At the fingerling size and up, most growers had circular tanks - either fiberglass, metal or plastic. Outdoor circular tanks had covers and the question regarding the necessity of covers arose since they add to the cost. At two sites, we were told of cases in which fry or larger fish died of suffocation when they all moved towards the outflow tube at the centre of the circular tank. This occurred when there was an abrupt increase in light intensity (e.g. light was flashed in the dark or the tank cover was opened to bright sunlight). One grower had no such problems when he used translucent covers on outdoor circular tanks. A few sites had concrete raceways, either inside a greenhouse or outside with no covers.

Some growers reported that fish were more "relaxed" at dim light levels and if they had hiding areas. One grower with special interests in the effects of surrounding structures on living organisms believed that there was a need for innovative structural designs that addressed the needs of both fish and man. This facility had hexagonal concrete tanks with covered areas where charr could "hide". In contrast, we saw charr successfully grown in a bright greenhouse in relatively shallow (1 m) tanks although there was one report of charr being sunburned in these tanks. While one person reported that charr will become stratified (ie. stacked in layers from bottom to top of the tank) at night in the dark and remain at the bottom in bright light, another person said that charr will stratify in bright light.

Two growers reported that the large light-colored or "grey" fish in the population reversed swimming direction in the fall and stopped feeding for several weeks. This may be related to migratory behavior. Concerns were expressed about the fact that fish did not feed when this occurred.

While tank characteristics were not expressed as an area of primary importance, they might be important in view of the diversity of systems that were being used. Tank shape and height of the water column have been shown to have a significant impact on the growth rate of Arctic charr (Tabachek, unpublished data). In addition, Scandinavian researchers showed that exercise, forced by water flow, resulted in increased weight gain of charr (Jobling 1990) as well as increased protein and decreased lipid content. More information on the combined effects of tank shape, size, light intensity, photoperiod, and flow directions and velocities are required.

Cage designs for outdoor freshwater, brackish and marine locations must be evaluated. These evaluations need to be conducted during all seasons and cages must be able to withstand winter ice conditions. Growers were interested in having the Kiel® cage evaluated. The cage environment offers fish a very different sense of space compared to a tank, and many concerns expressed for tanks, as well as ones unique to cages must be addressed. Appropriate cage sizes and stocking rates must be determined. Little is known about the ability of Arctic charr to feed in cages. Any information in these relatively unresearched areas will be of value, especially if comparisons are made at one site.

8.2 Recirculation technology

At present, the number of sites for raising charr are limited by the availability of water. One way to increase the number of suitable sites for aquaculture is to reuse the water by biofiltration and recirculation. Although a limited amount of information on design and operational characteristics is available (Vandenbyllaardt and Foster 1992), additional research in this area is required to perfect designs and reduce the amount of labor required in maintaining the systems.

8.3 Heat pumps and exchangers

Heat pumps and exchangers were in evidence throughout New Brunswick. Systems should be compared and the information made available. The systems were reported to be very expensive and information on the economics and cost-effectiveness of using them is needed by growers raising all species - not just Arctic charr. This research might be conducted jointly by government and industry or by manufacturer and industry.

9 SITE EVALUATION

Site evaluation was a topic which was raised on a number of occasions. Each province has specific areas that are suited to fish culture. More information on suitable culture conditions for Arctic charr and descriptions of successful sites will make future site selection easier. (See Priorities 4 and 8).

10 DISEASES

Throughout Atlantic Canada, there was almost no mention of diseases of charr being a problem. There was evidence that certain diseases in charr were related to the stress of "higher" water temperatures, and that the incidence could be prevented or reversed by lowering temperatures. Brown et al. (1991) from Memorial University showed that proliferative kidney disease is induced more easily in Labrador charr at 12-14.9°C than at 10-11.9°C, the latter range being close to the average Fraser River water temperature. More research of this type would be of value, particularly if different strains and stressors other than temperature are evaluated.

11 TRIPLOIDY

Interest in triploid charr was expressed by only a few people. One person considered production of sterile fish as a way of ensuring that aquaculture stocks which escape from cages would not breed and compete with wild stocks. Others, who wanted to raise charr to market at the 1.8-2.7 kg (4-6 lb) size, considered it to be a way to prevent sexual maturation before reaching this size. Another person believed that triploidy might be a better solution than selection for late maturation for overcoming variation in size. Research on triploidy of Arctic charr is being conducted at RARC by M. Papst of the Freshwater Institute Science Laboratory and T. Dick of the University of Manitoba.

12 SWIM BLADDER SYNDROME

Swim bladder syndrome (seen as fish swimming with a portion of their back out of the water) was seen at only one facility which had large fish. A Norwegian researcher reported this to be caused by the stress of shallow water. This should be investigated for Canadian charr because all the growers and researchers who discussed this topic believed that water depth was an unlikely cause of this syndrome.

13 QUALITY OF PRODUCT

The type and quality of product produced at different sites under different conditions was a concern to many growers because establishing a market identity depends on the product being consistent. Research must relate to producing fish of a consistent size and quality.

There is a need for information on how quality (appearance, flavour, texture) is affected by feeds and by the environment. Growers said they needed information on the effects of stocking density, recirculation and specific water quality parameters, such as ammonia and dissolved oxygen, on the quality of fish. In regards to recirculation, the practice at RARC is to stop feeding fish and to change the water supply from recirculation (10-12°C) to single-pass water (6-7°C) for 7-10 days before fish are slaughtered. This has been found to improve the flavor and possibly the texture. However, there has not been any scientific research done on this subject.

14 SUPPORT SYSTEMS

The need for market surveys, training and improved communication within the Arctic charr industry was expressed often throughout our trip. While not research priorities, these topics are discussed here because of their importance to the industry.

14.1 Communication

There is a great wealth of knowledge and experience amongst researchers and producers in raising Arctic charr. However, they are generally isolated from each other and the expense of travel limits their contact. Some of this knowledge has been published but there is much information that may never be published in the scientific literature. Robbins et al. (1990) published a manuscript that incorporated a lot of previously

unpublished Scandinavian literature on Arctic charr. A publication similar to this but which presents unpublished Canadian literature would be useful. Information based on scientific experiments also needs to be stated in a manner that makes it applicable to the producer.

During our trip, we heard many interesting observations about raising charr as well as comparisons with other species. There needs to be a mechanism that will enable growers to express their observations and concerns and share their approaches to overcoming problems.

In June 1990, we initiated an Arctic charr Culture Bulletin to provide information to clients to whom we have shipped Arctic charr eggs. We plan to continue this annual publication. W. Van Toever of Prince Edward Island, suggested that Arctic charr growers and researchers need to form "networks" to keep informed. He plans to investigate other ways of providing mechanisms for both growers and researchers to communicate.

The Central and Arctic Region would like to host a national or international Arctic charr Culture Workshop in Winnipeg. The central location of Winnipeg would encourage participation from growers and researchers from across Canada. Proceedings from this workshop would also provide a forum for publication of data that has not yet been published. Presenters would be asked in advance to submit their presentations in a publishable form. B. Glebe of HMSC in New Brunswick has also expressed interest in hosting a workshop. He suggested that there might be a National Workshop followed by Regional Workshops to disseminate the information to other growers and researchers who may not have the opportunity to attend.

14.2 Training

There are differences between methods for spawning and rearing Arctic charr, rainbow trout, and Atlantic salmon. There is a need for "hands-on" training from people with experience with Arctic charr. J. Delabbio of the New Brunswick Community College, St. Andrews, NB, has visited sites during spawning season and demonstrated the techniques for spawning Arctic charr. She believes this training is essential to rearing it successfully. Similarly, several clients who have received eggs from RARC have also received training. They have come to RARC at appropriate times of year to receive training in spawning and early rearing of Arctic charr, or provided travel funds for R. Olson, Fish Culture Manager, to visit their facility and demonstrate techniques.

14.3 Marketing

Although there have been market studies conducted for Arctic charr, some of these have been funded by private companies and the information is proprietary. Two published reports include a study on the market interaction of wild and farmed charr (Smith 1989) and a market survey conducted in Winnipeg as part of a university graduate thesis (Hathaway 1987).

While many growers expressed the need for market surveys or the desire to do market surveys, they had two main problems with such surveys. First, growers must produce sufficient fish or fish products for the survey before they can determine whether there is a market for it. Yet, they cannot determine if there is a market unless they invest in producing the product. Secondly, they believed that the information generated by such a survey becomes outdated very quickly. Growers must react to a market survey very quickly, which is difficult if the fish have not reached market size.

Growers also expressed the desire to develop marketing cooperatives as a way of stabilizing prices and providing a continual supply of fish. Several growers have bought licenses for Brandy Cove® Arctic charr through the HMSC. As licensees, they have purchased access to marketing information and a marketing cooperative.

CONCLUSIONS

A diversity of research opportunities exist for Arctic charr culture with research areas that differ in both size and scope. Contributions to increasing the knowledge about this species can be made at both large and small facilities. While large-scale experiments may be required to answer some questions, small-scale experiments can yield important information in some areas. The opportunity may exist for growers and researchers to conduct cooperative experiments. This would provide researchers with access to fish, tanks and technical support and provide growers with the ability to contribute to improving culture techniques. In addition, it could give growers access to funding through programmes such as Atlantic Fisheries Adjustment Program (AFAP) and Industrial Research Assistance Program (IRAP). Whether research is conducted cooperatively or individually, research on the high priority areas described here will benefit the culture of Arctic charr by the industry.

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APPENDIX A

PEOPLE WITH WHOM WE MET

New Brunswick

Corey Feed Mills Ltd.
Ivor Bernatsky
Terry Drost

Moore-Clark Co. (Canada) Inc.
Steve Backman
Sam Bowman

Bouctouche Mic Mac Band
William Sanipass, Chief

Daigles Fish Farm
Douglas Daigle

Green Acres Trout Hatchery
Robert Methe

Purtill "B" Fish
John Cushne
Brian Chown

Sea Farm Canada
David Bowes

GTA Fisheries Consultants
Christian Noris

Huntsman Marine Science Centre
Brian Glebe

New Brunswick Community College
Julie Delabbio

New Brunswick Dept. of Fisheries and Aquaculture
Michel Desjardins
Marcel Leger
Kim Lipsett
Hugh Madill
Denise Methe
Pierre Rioux
Robert Rioux

Department of Fisheries and Oceans
Keith Atwin
Malcolm (Sandy) Campbell

Nova Scotia

Merlin Fish Farm
Paul Merlin

Salmonid Propagation Assoc. Coop. Ltd.
Robert Cotton
David MacNearney

T.W. Strickland Farms Ltd.
Whit Strickland

Sugarloaf Fish Farms
Gary Gordon
Chris Ripley

John Gormley

Carl Veinotte

Nova Scotia Department of Fisheries
Murray Hill
Don MacLean

Prince Edward Island

Integrated Aquatic Systems Ltd.
Joe Boyer
Roddie Milton
Terry Morrison
Wayne Van Toever

Atlantic Veterinary College
University of Prince Edward Island
Maura Jansen

P.E.I. Dept. of Fisheries and Aquaculture
Richard Gallant
Edgar Mason

Newfoundland

Aquametrica
Nigel Robbins

Bay D'Espoir Salmon Hatchery Ltd.
Arnold Sutterlin

New Tech Char Farms Ltd.
Robert Freeman

Trinity Blue Aquafarms Ltd.
Graham Bailey

Valley Char Inc.
Todd Turner

Bonaventure English Harbour Dev. Assoc.
Fred Rex

Enterprise Nfld. and Labrador Corp.
Sheila Fudge
Beth Payne

The Venture Centre
Shawn Robinson

Newfoundland and Labrador Institute of
Fisheries and Marine Technology
Marine Institute
Steve Goddard

Memorial University
Ocean Science Center
Joseph Brown
Laurence Crim

Memorial University
Biochemistry Department
Fereidoon Shahidi

Provincial Department of Fisheries
Brian Meaney
Ron Scaplen

Department of Fisheries and Oceans
Irwin Carpenter
Brian Dempson
Randy Penney
Vern Pepper
Jerry Pratt
Terry Quinton
Larry Yetman

APPENDIX B

PEOPLE CONTACTED ONLY BY TELEPHONE

New Brunswick

Department of Fisheries and Oceans
Maurice Mallet

Nova Scotia

Nova Aqua Smolts Ltd.
Ross Bennett

Mic Mac Smolts Ltd.
Michael Mullen

Prince Edward Island

Brook Valley Hatchery
Sefton Dixon